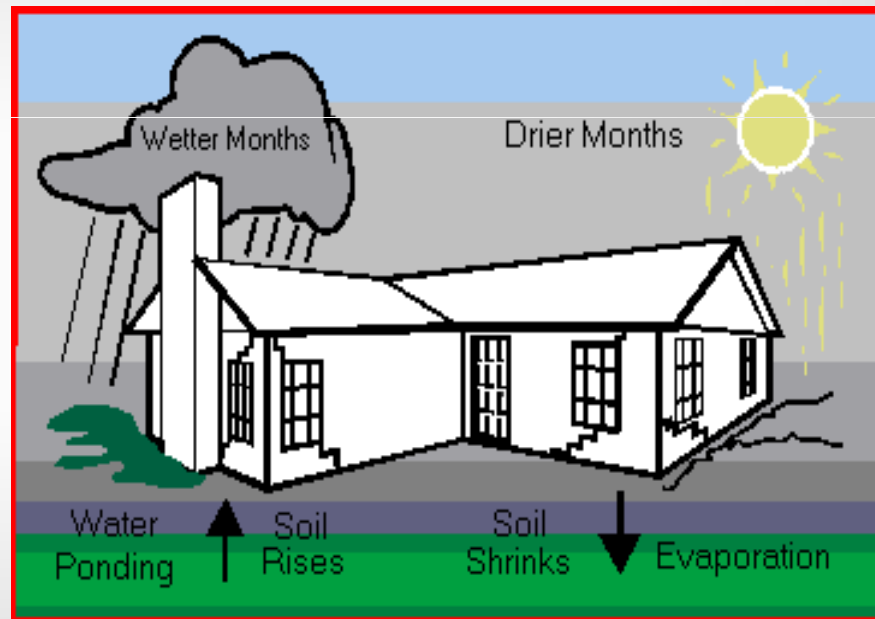


Subsurface Void Detection for the Foundation Performance Association

Causes of subsurface voids

Causes of subsurface voids

- Expansive soils



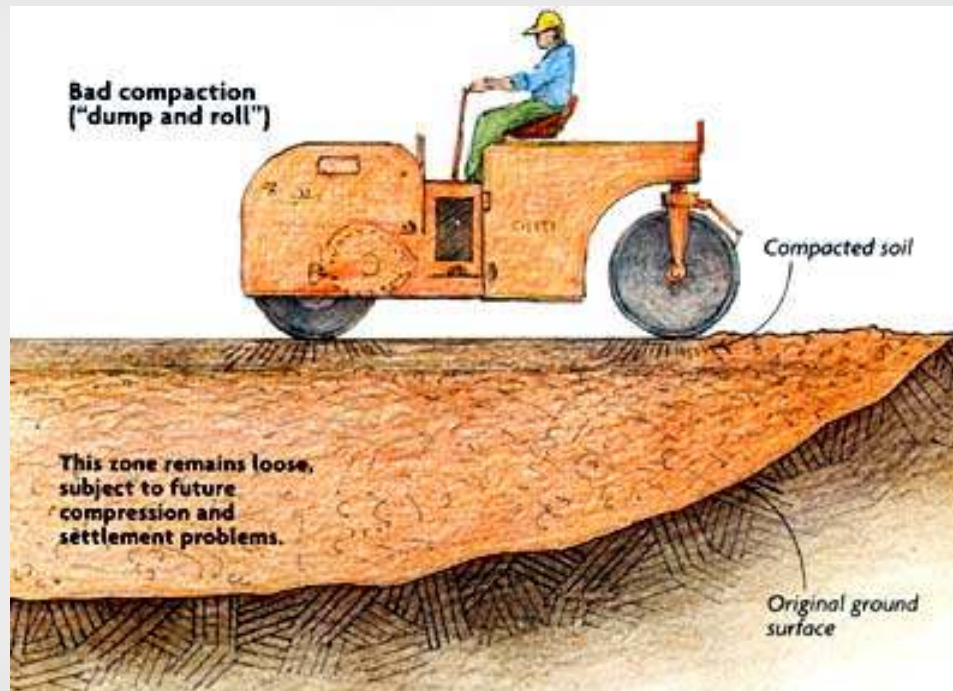
Causes of subsurface voids

- Poor drainage



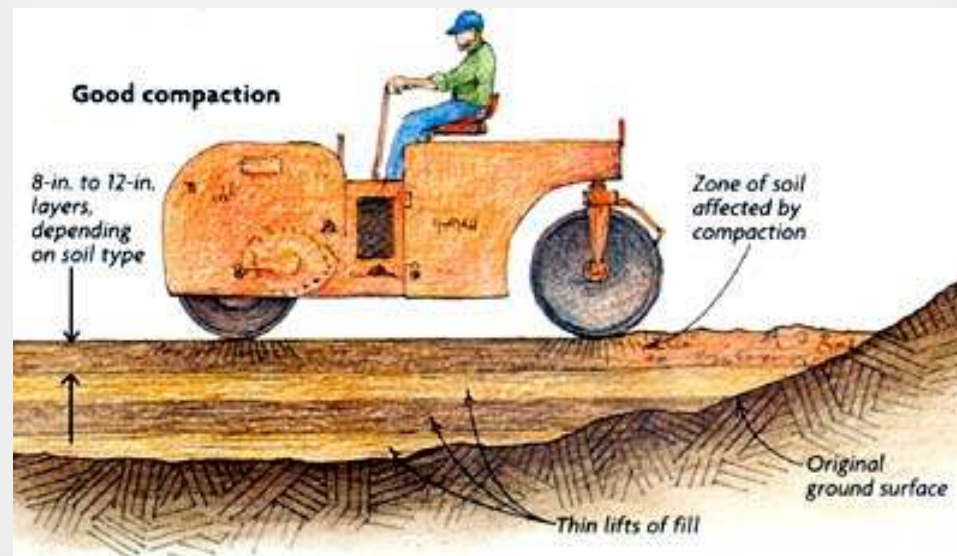
Causes of subsurface voids

- Poor compaction of soil - wrong way



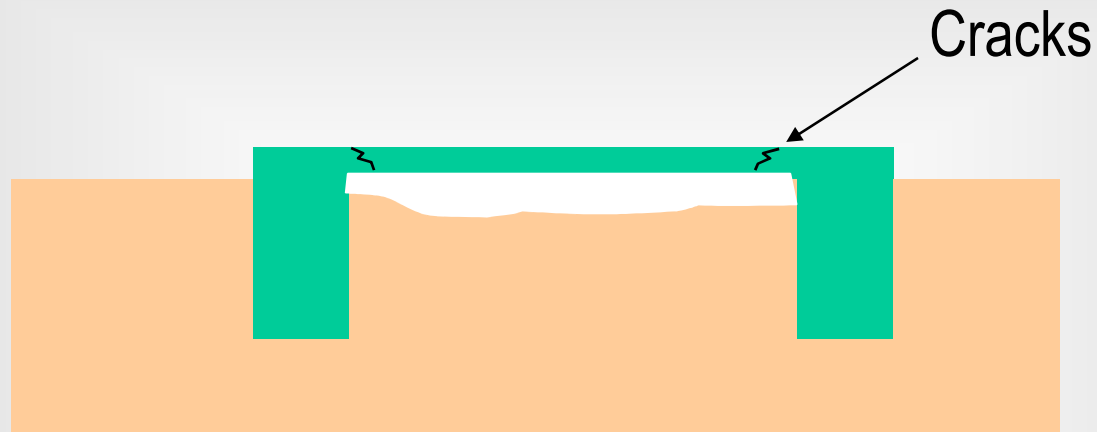
Causes of subsurface voids

- Poor compaction of soil – right way



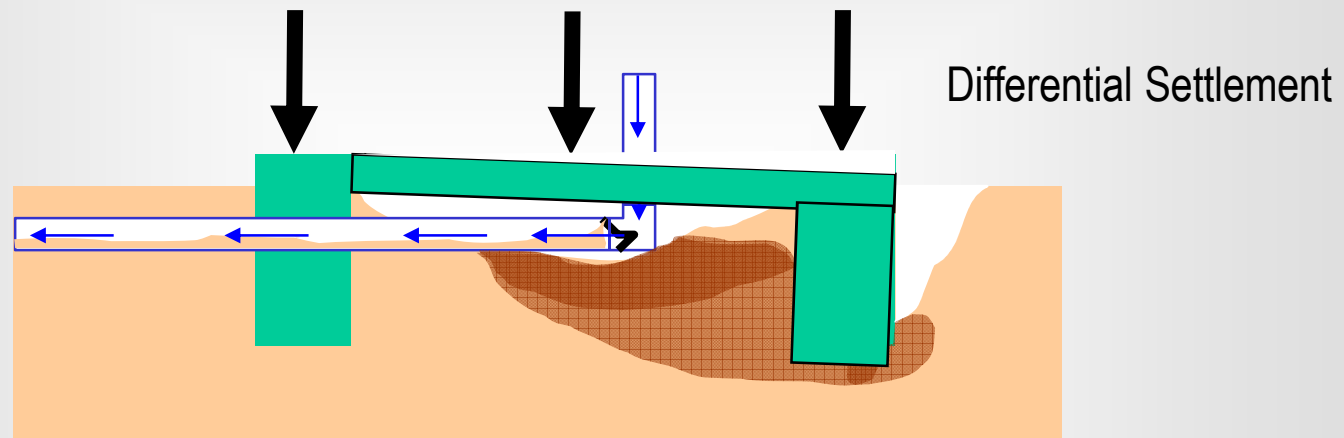
Causes of subsurface voids

- Poor compaction of soil - effect



Causes of subsurface voids

- Leaking Utilities / drainage systems



Causes of subsurface voids

- Leaking Utilities / drainage systems



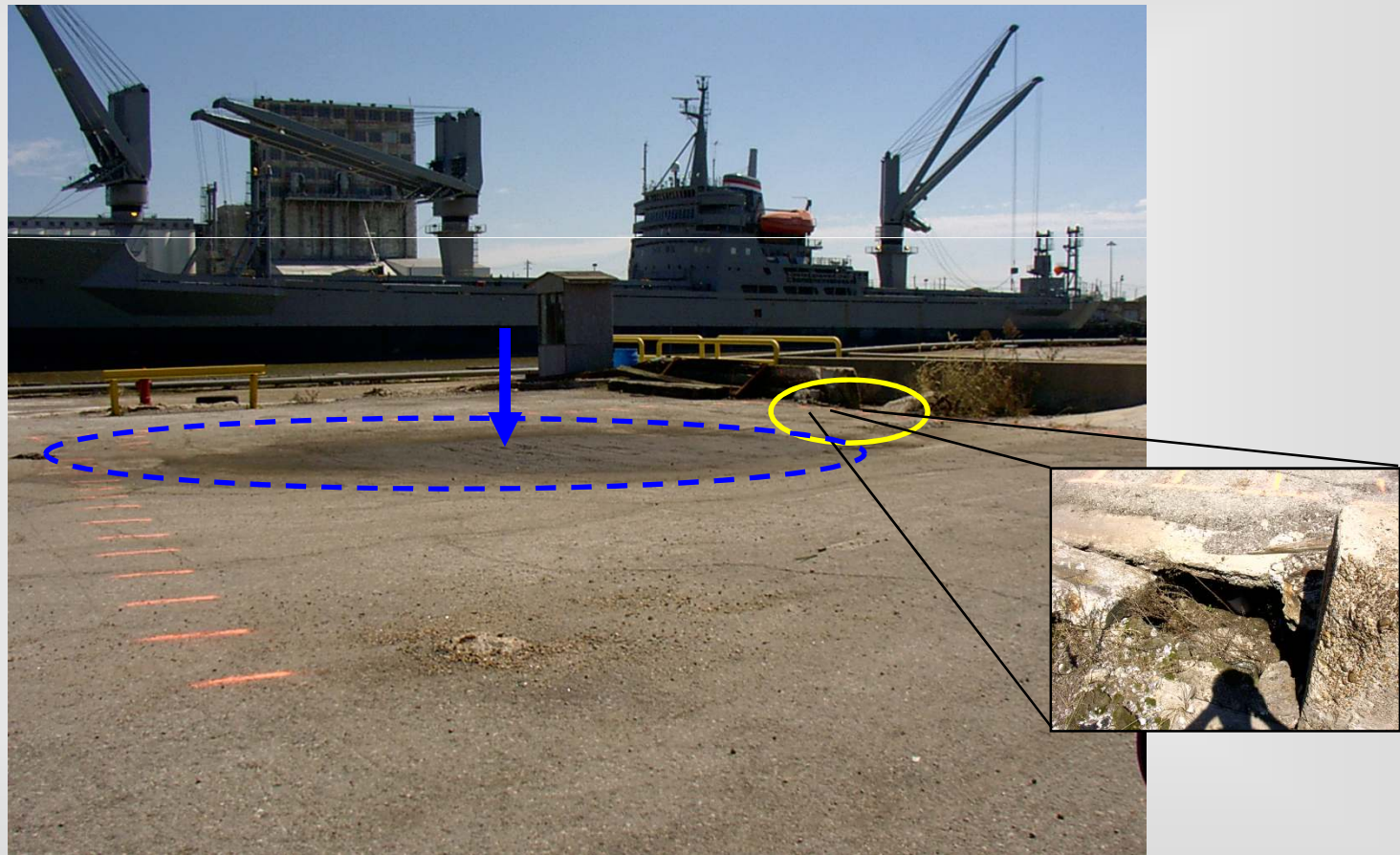
Causes of subsurface voids

- Leaking Utilities / drainage systems



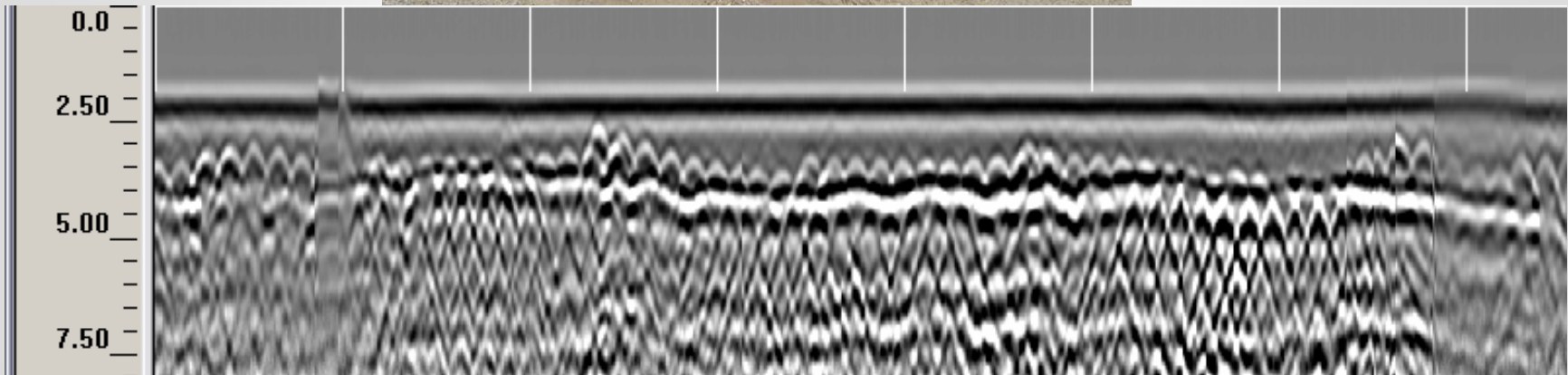
Causes of subsurface voids

- Leaking Utilities / drainage systems



Detection Methods

•Ground Penetrating Radar (GPR)



Introduction to GPR

- Early usage: Austria 1929, Military 1950's
- 1st commercial system developed in the early 1970's for use in Geotechnical applications
- Advanced 3D Software developed in the late 1990's
- Uses Electromagnetic Wave Propagation to measure changes in electrical and magnetic properties
- Allows Non-Intrusive look into or through low-conductivity materials
- Used in Geophysical, Structural, Civil, and other industries

Two electrical properties of importance to GPR surveys

- Electrical Conductivity – effects penetration
- Electrical Permittivity “Dielectric Constant” – effects the reflected signal strength

Detection Methods

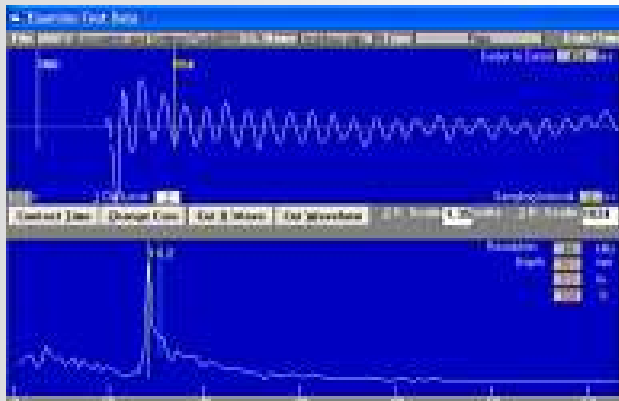
Forms of GPR

- Single and two-channel systems are most commonly used for foundations, bridges, buildings, short road sections
- Multi-channel and phased array systems are used for high speed long sections of highways



Detection Methods

- Impact-Echo



Introduction to Impact-Echo

- Research began as early as 1983 at the National Bureau of Standards (NBS) now known as National Institute of Standards and Technologies (NIST)
- The first thesis research was performed at NIST and accepted in 1986 by Cornell University
- 1st commercial system was available in 1992
- Uses Impact-generated stress waves that propagate through a concrete and masonry structures
- Used in Structural, Civil, and other industries

Impact-Echo

- Stress (sound) waves that propagate through concrete and masonry are reflected by internal flaws and external surfaces
- Primarily used to determine defects in concrete structures. It can also locate voids in the subgrade directly beneath slabs and pavements.
- Accurate method, but slower than GPR for voids surveys

Detection Methods

Core Drilling



Core Drilling

- Core Drilling – effective to verify a suspect location but would require many holes in order to “Survey” an area for voids.
- Will not give a true indication of the void size in sq. ft.
- Destructive – effects aesthetics, carpet, flooring, cuts PT cables, rebar & utilities

Order of use:

1. Void survey: GPR
 - Used to quickly screen large areas, providing an accurate plan view map of voids as well as determine the depth
2. Localized prove-up:
 - Core Drilling

Other Detection Methods

Dynamic Cone Penetrometer – works reasonably well, however it is labor intensive and inefficient. ASTM STP-399

Proof of concept demonstration

Detection Methods



Warehouse floor

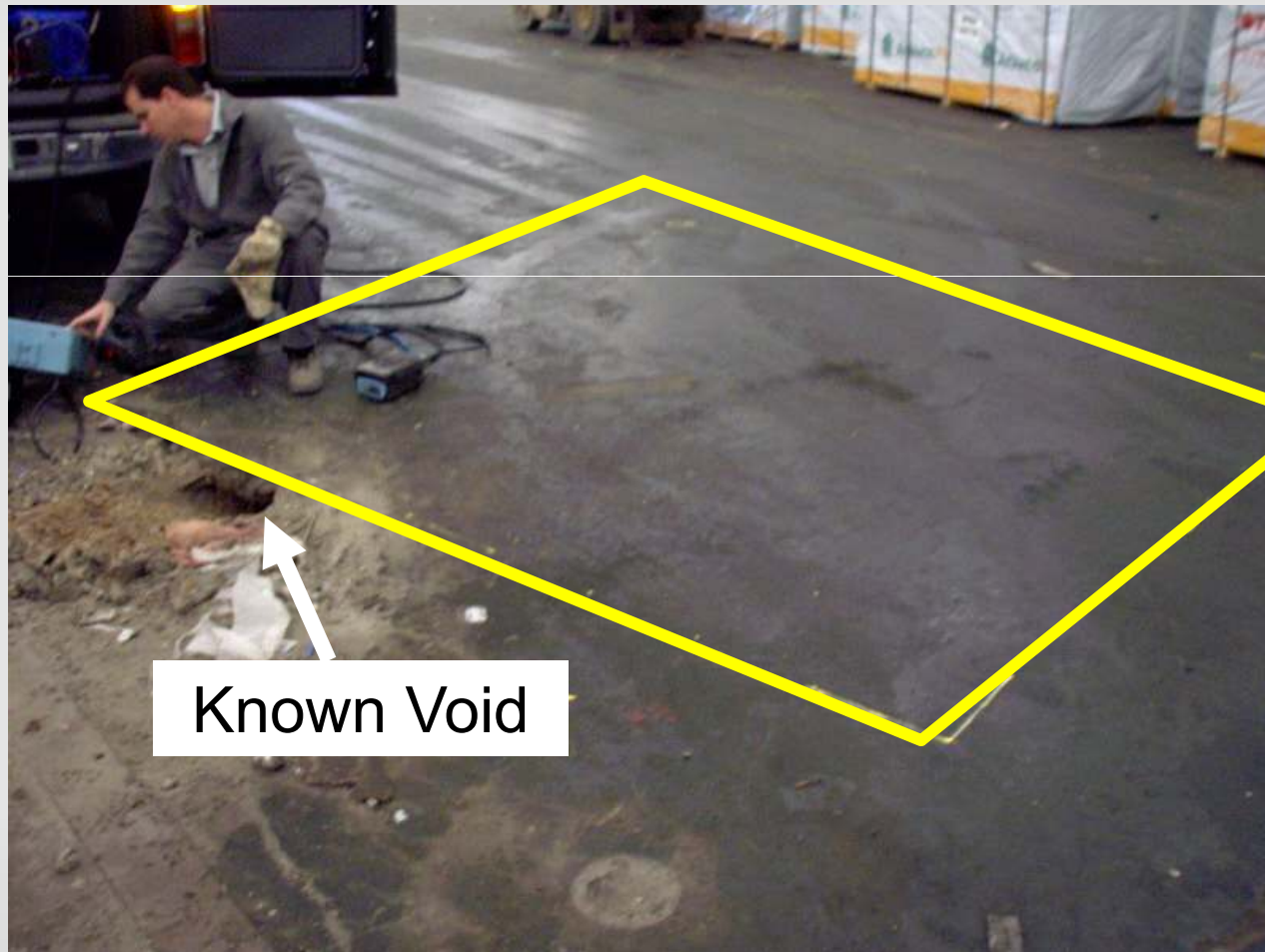
- Heavy trucks cracking the slab
- Proof of concept void detection and sizing
- NDE technologies:
 - GPR
 - Laser Elevation survey

Detection Methods



Slab failure near exterior grade
beam due a large void.

Scan Area



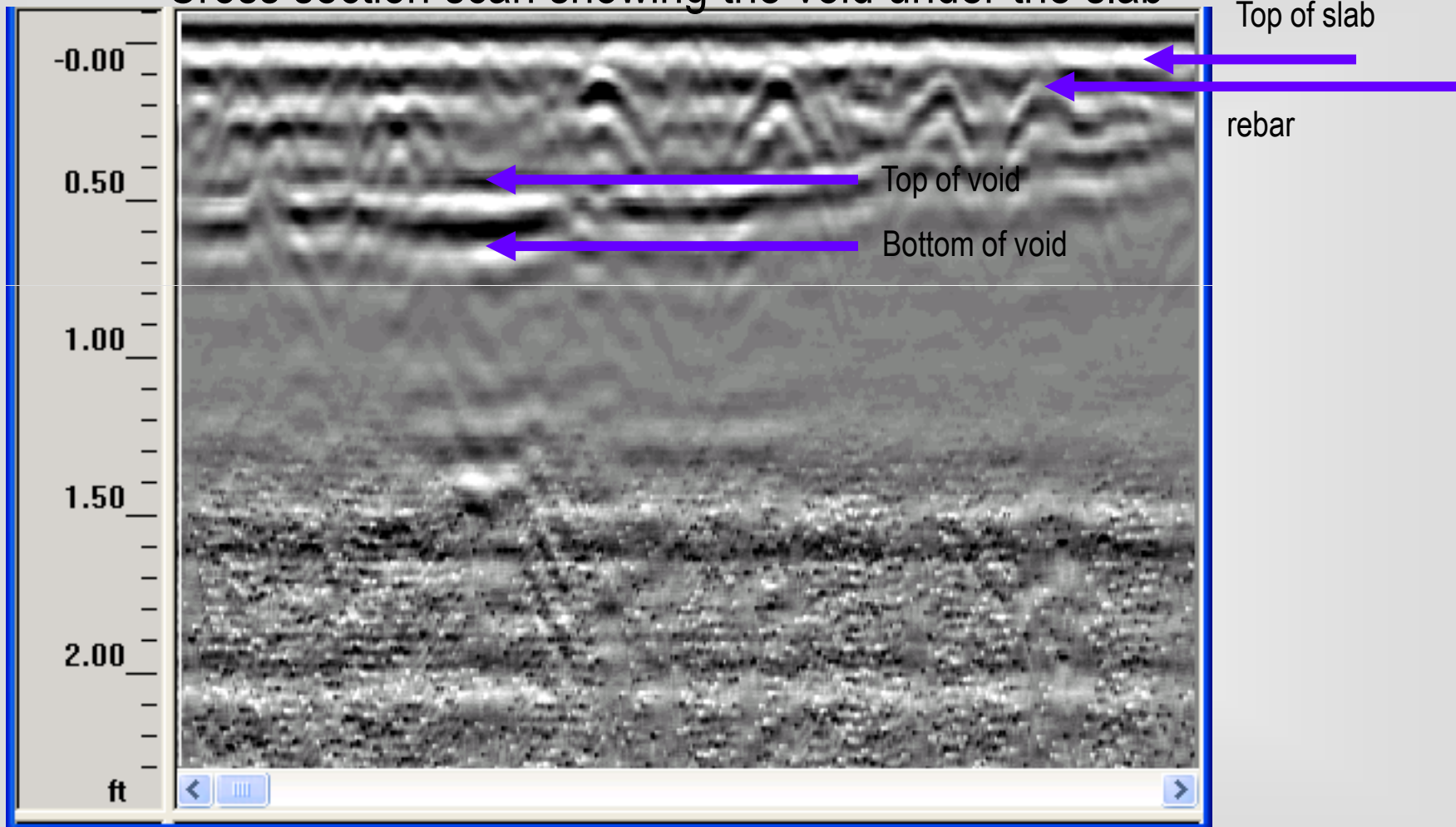
Detection Methods



**Known Void vertical depth:
Approximately 3" as measured**

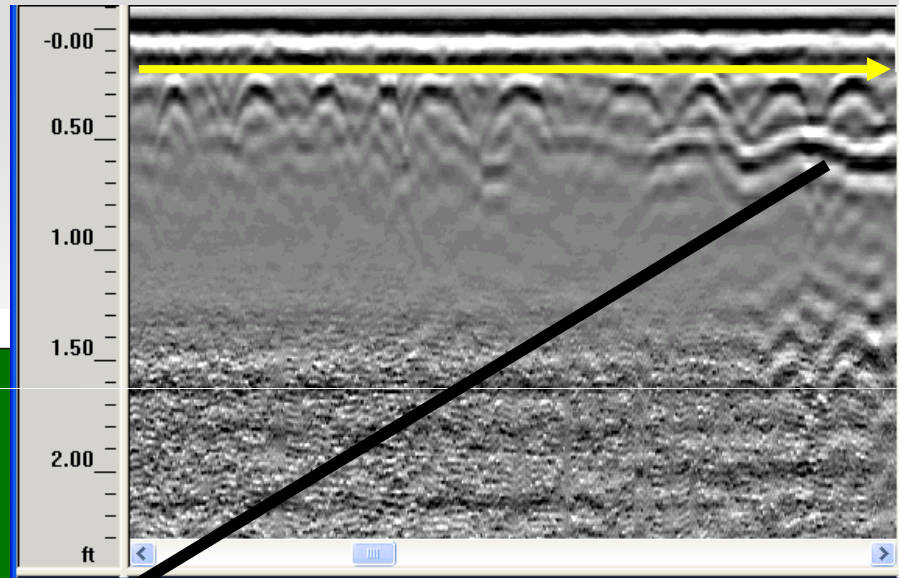
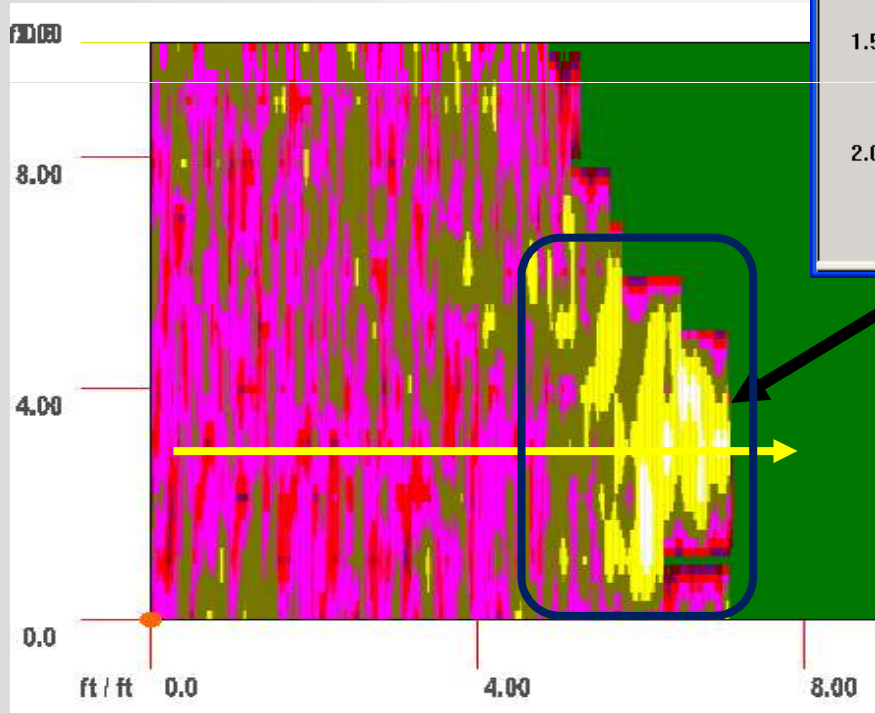
Detection Methods

Cross section scan showing the void under the slab



Detection Methods

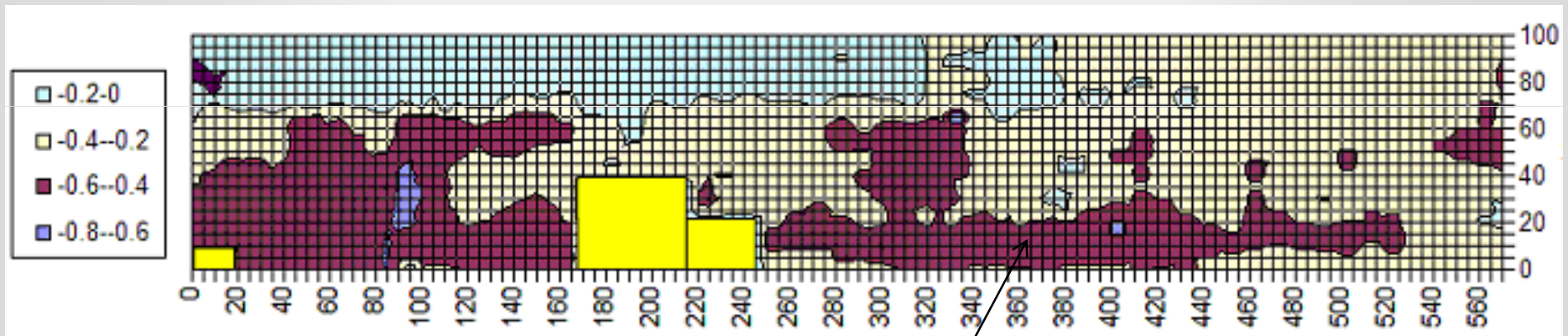
Cross section scans
merged into plan view
to show the void.



Yellow arrows indicate scan direction

Dark blue outline indicates the
area of the void

Detection Methods



560' x 100' void & elevation survey

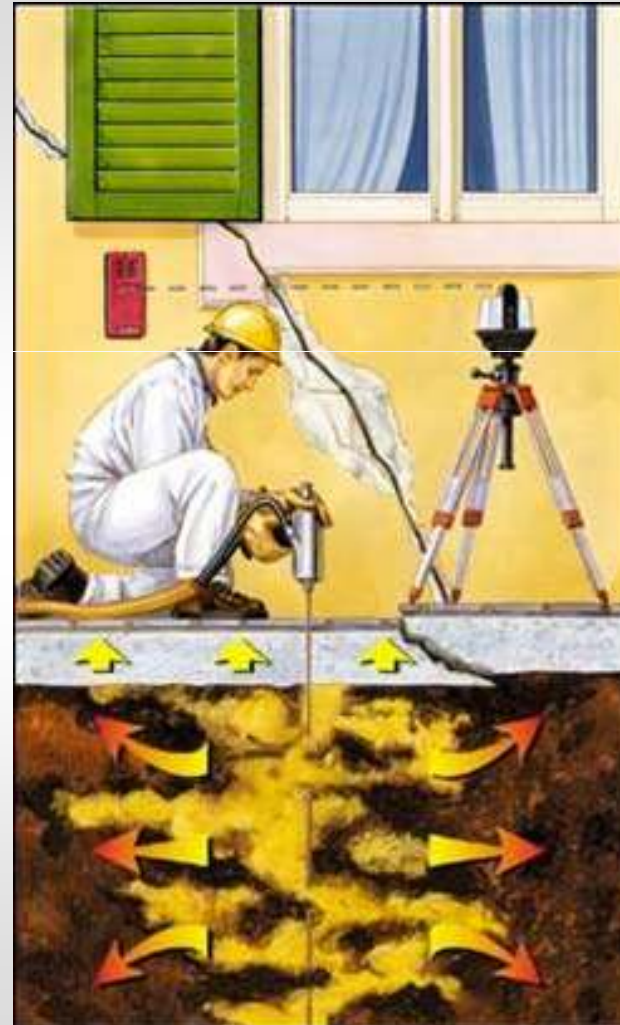
Yellow: Offices in the warehouse.

The darker outlines indicate the void area

Void Repair Options

Void Repair Options

- Urethane Injection
- Grout Injection
- Mud Jacking



Void Repair Options

Visible settlement



Void Repair Options

After lifting the slab



Residential Void Case Study

Voids beneath foundation slabs



New construction home

Problem:

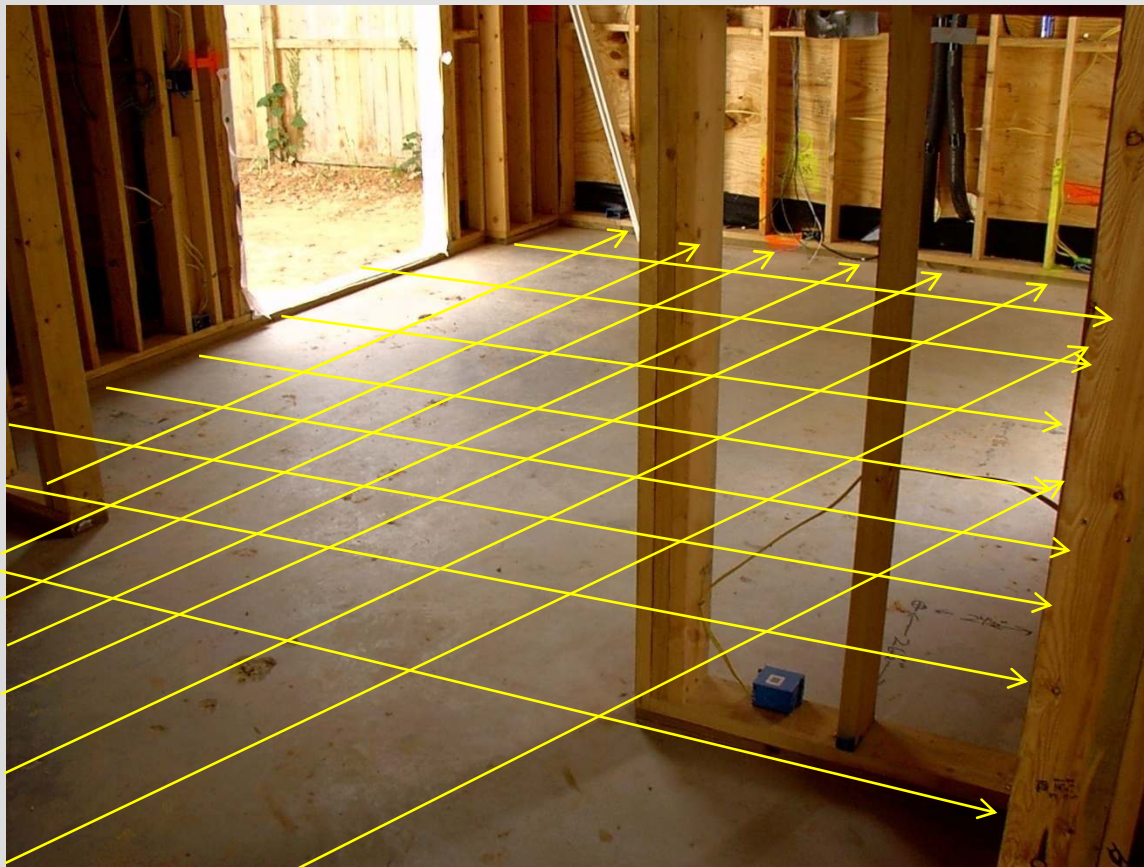
Subsidence observed around the foundation perimeter of the study and foyer

Investigate for a possible void under the slab

NDT Technologies

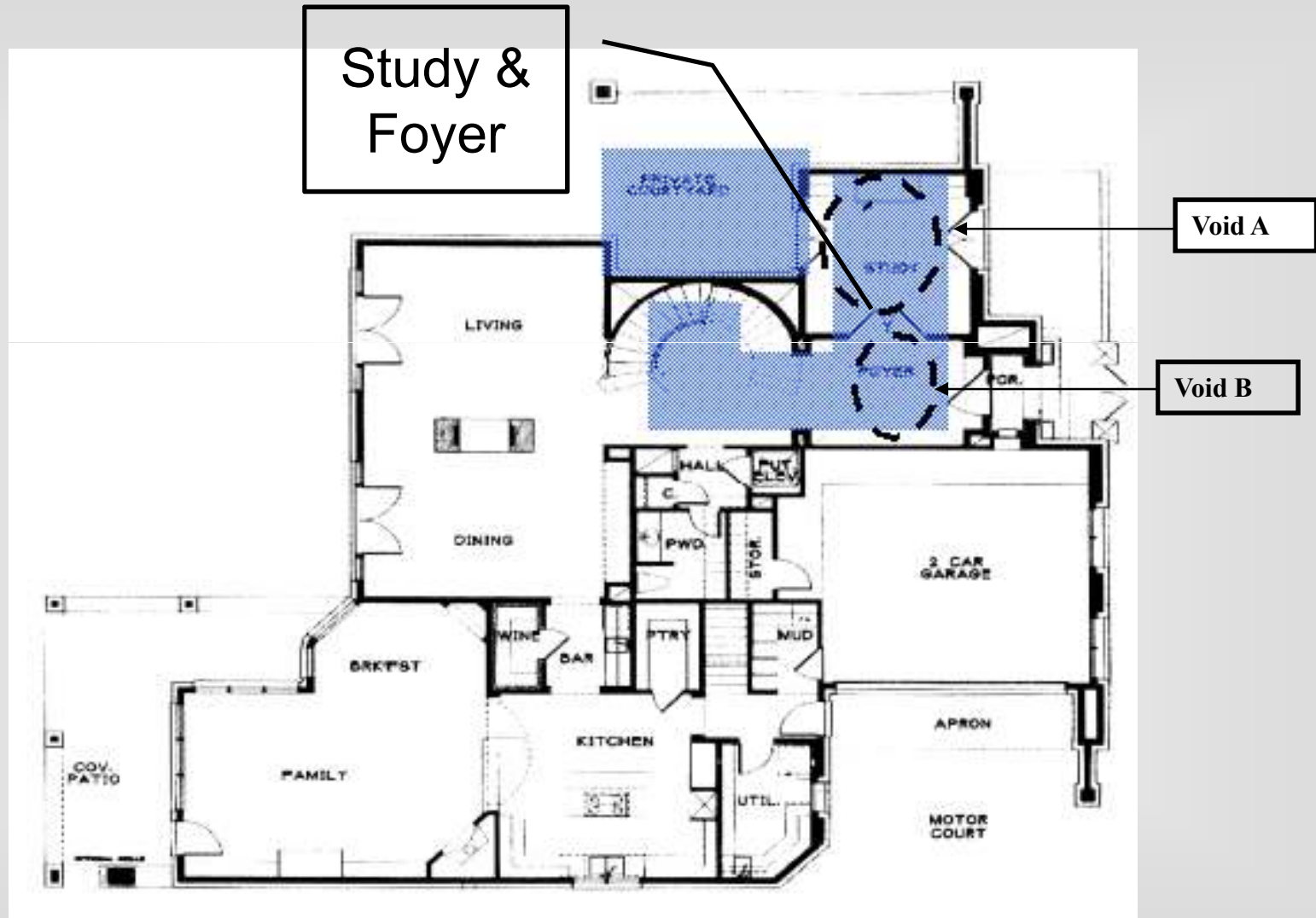
– GPR

Voids beneath foundation slabs

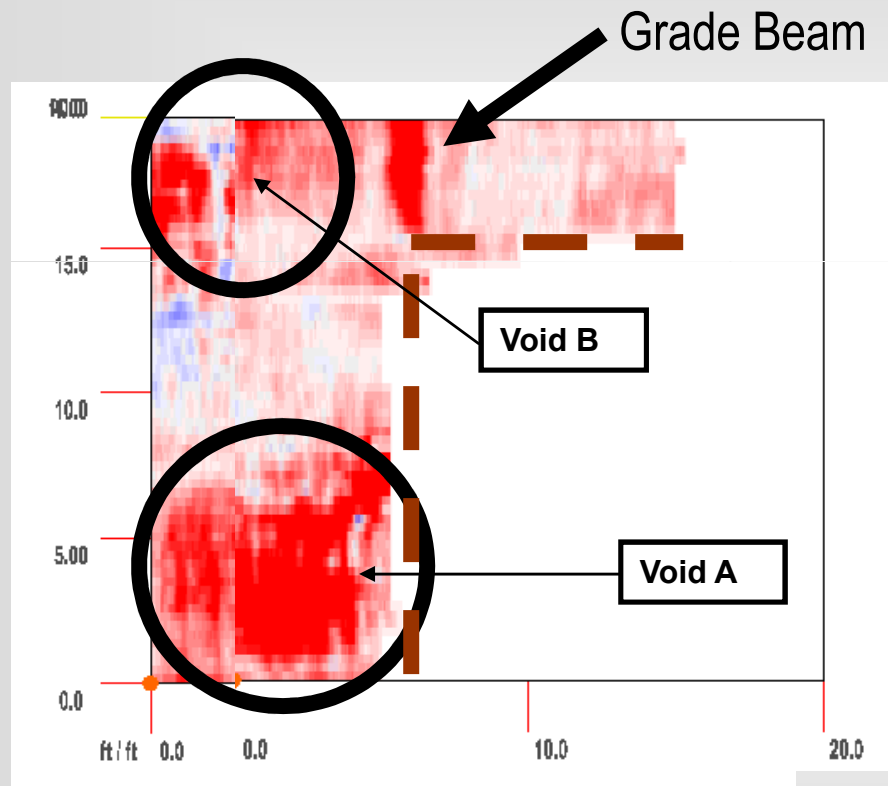


Study and Foyer were scanned used a 6" grid pattern

Voids beneath foundation slabs



Voids beneath foundation slabs



Voids were found in two locations
Geotechnical Engineering Review
Determined the cause to be
poor compaction of fill
A contractor was mobilized to
pump flowable fill into the voids

Voids beneath foundation slabs

**Void detection inside a small
office/warehouse**

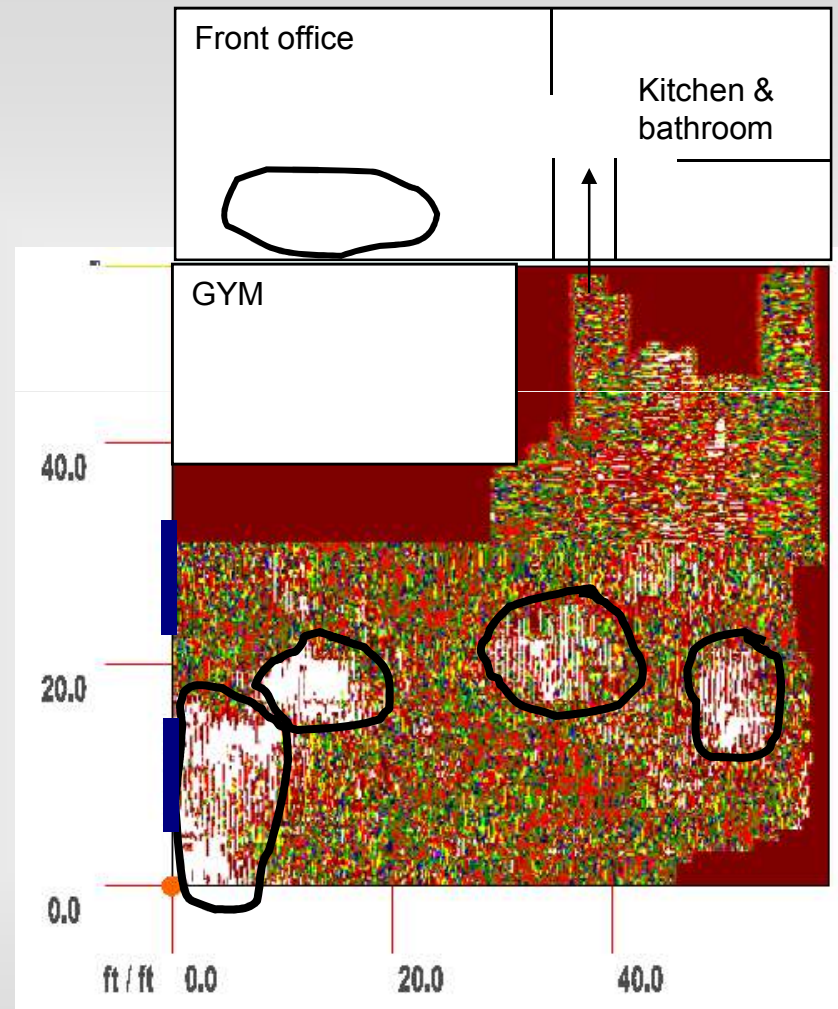
Voids beneath foundation slabs



Problem:

Client observed settlement in the offices and warehouse floor. The visible settlement was about 1-2".

Voids beneath foundation slabs



Problem:

The black outlines indicate the void locations.

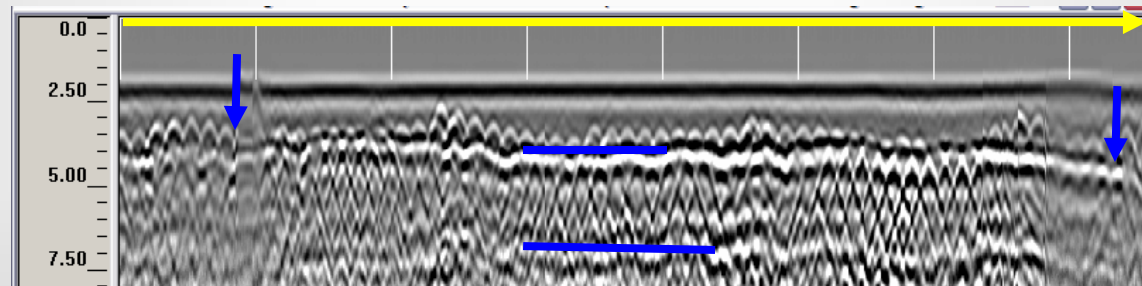
The front office void is detailed on the following slide.

Voids beneath foundation slabs



Front office slab was broken out to verify the void and repair utilities.

Voids are evident throughout the scan (2-3" deep).

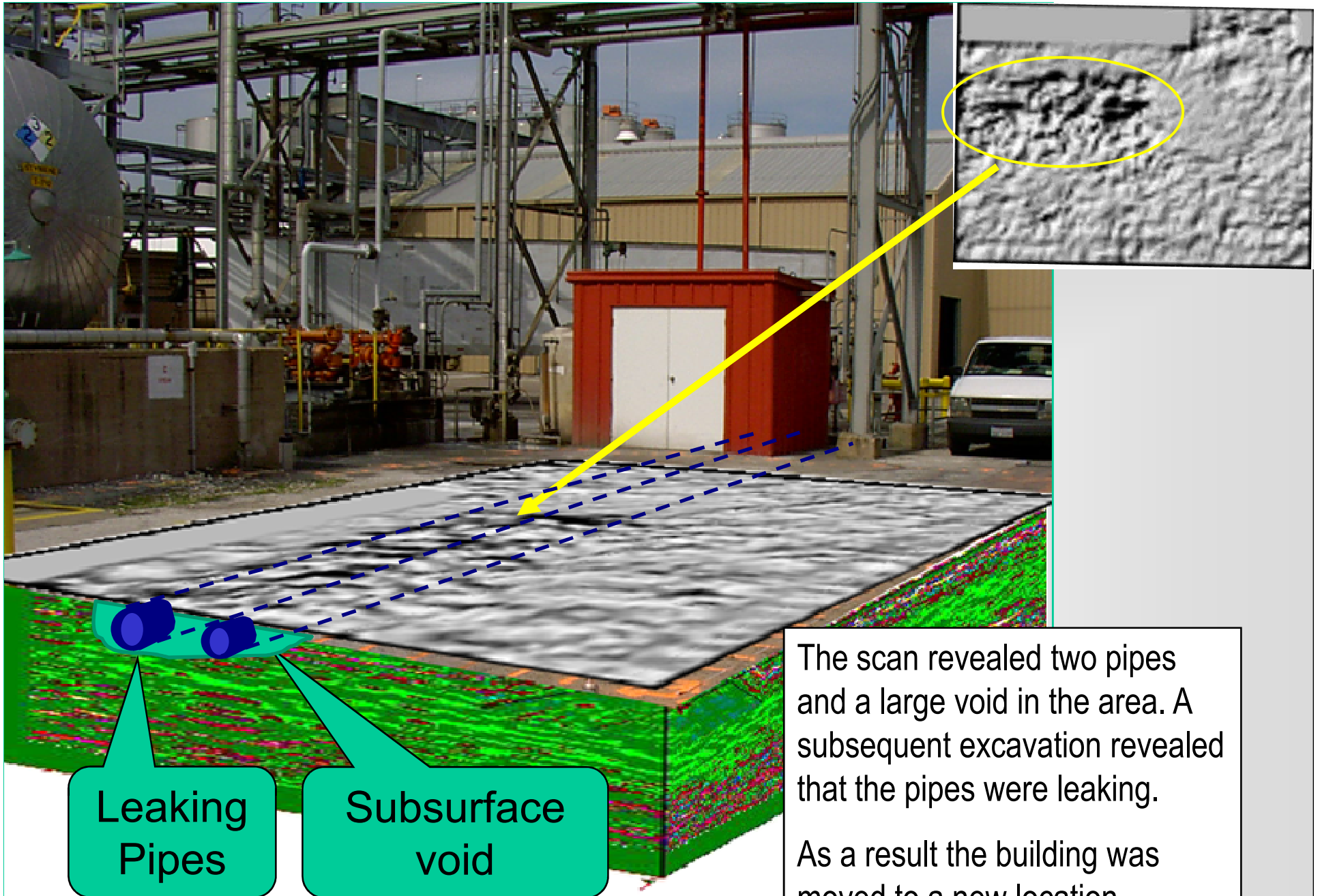


Proposed foundation location for a
new industrial control room building.

Proposed foundation location



The orange paint outline shows the area to be examined.



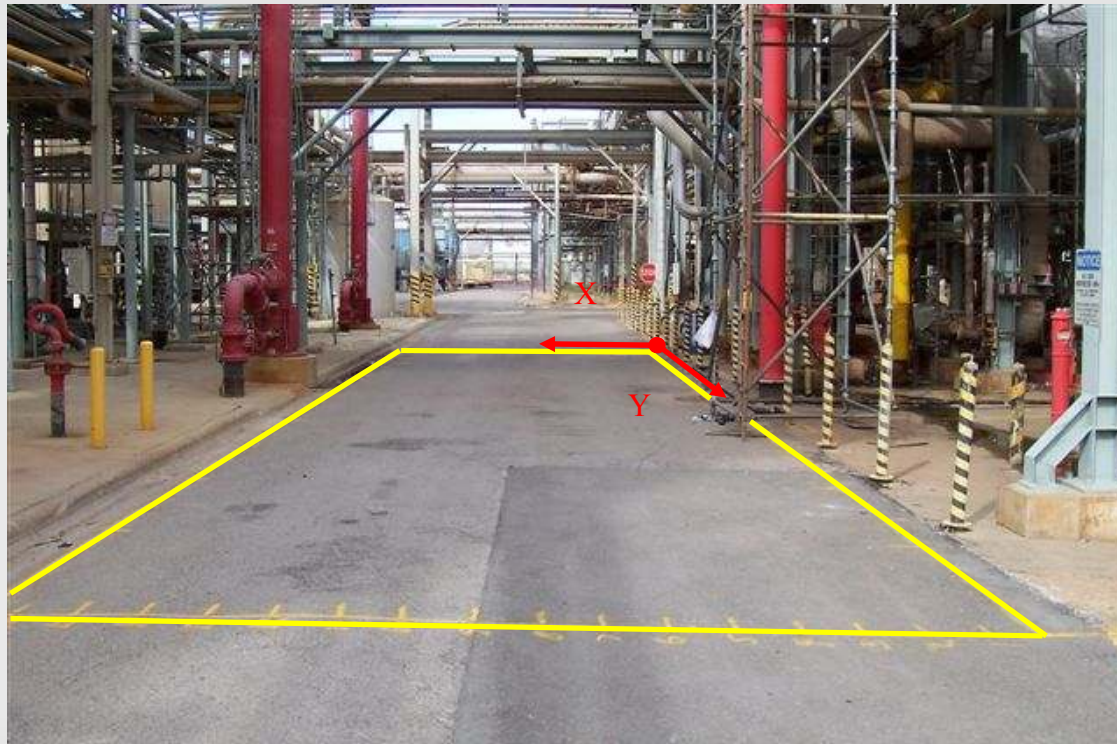
Pavement Evaluation

Effects of voids on pavement

Pavement Evaluation

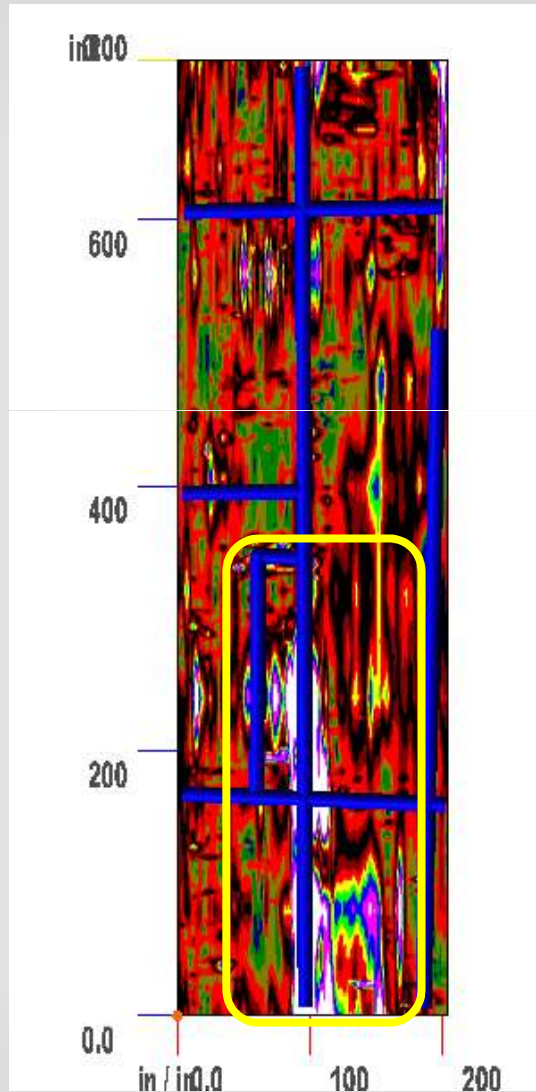
Pavement within an industrial facility

Pavement Evaluation



The area to be examined is outlined above.

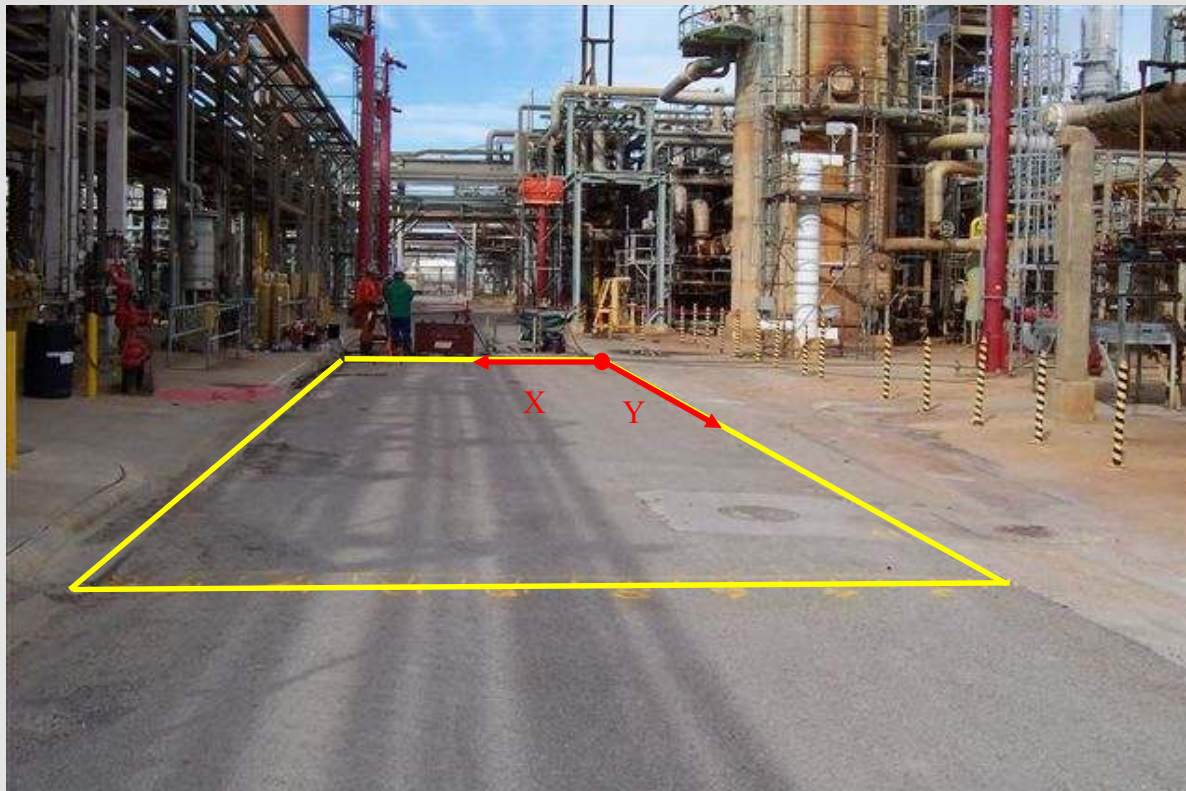
Pavement Evaluation



The image to the left shows pipes detected as well as a leaking connection and void.

The void and saturated soil from the leak are outlined in yellow.

Pavement Evaluation

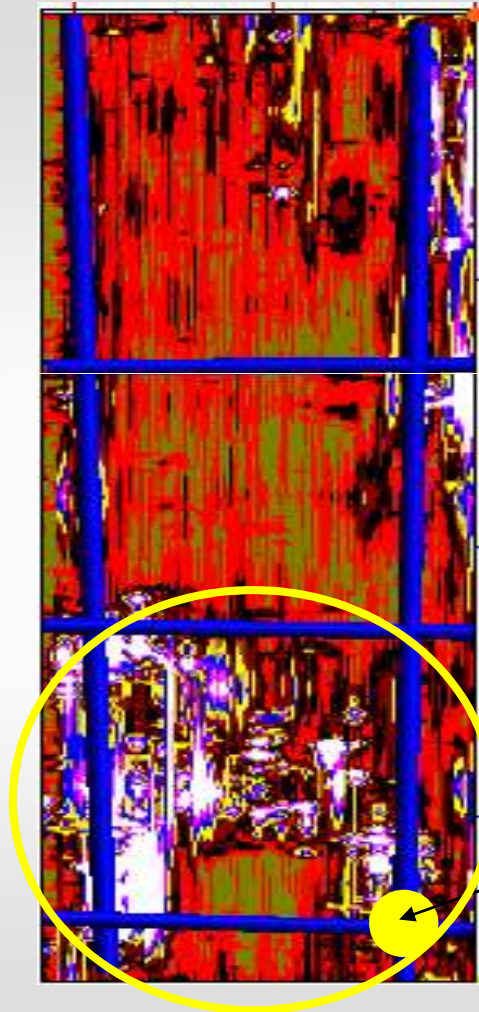


The area to be examined is outlined above.

Pavement Evaluation

The image to the right shows the pipes detected as well as a leaking manhole and void.

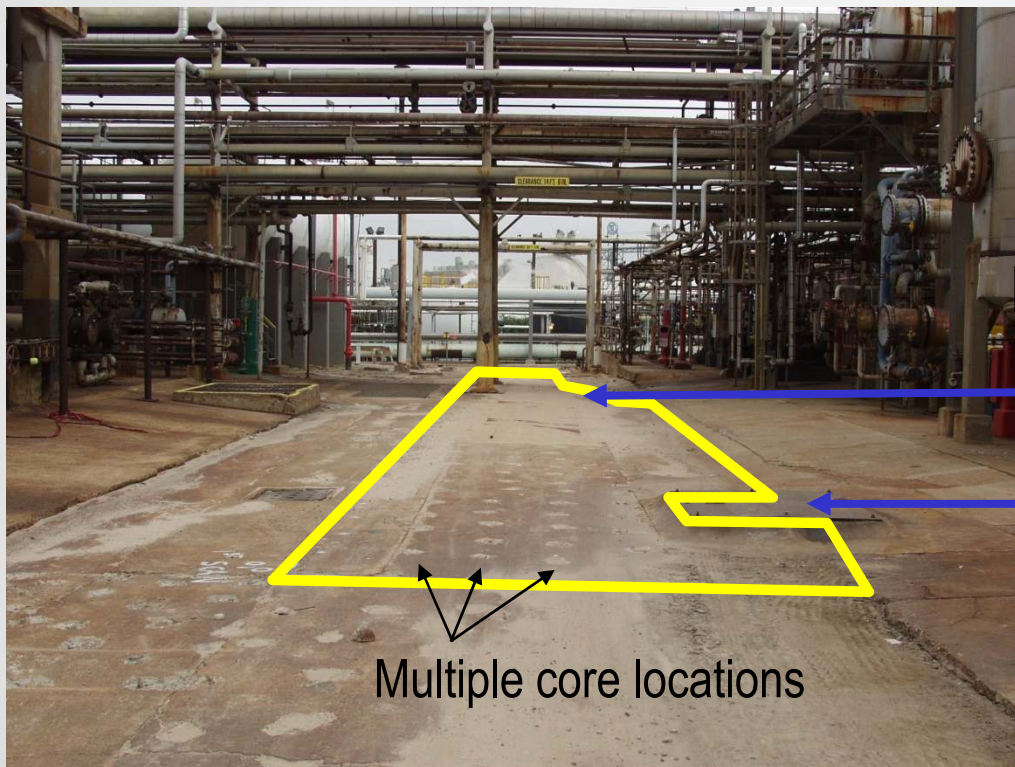
The void and saturated soil from the leak are outlined in yellow.



Manhole

Pavement Evaluation

Problem: Concern about placement of a large crane in the roadway and general vehicular traffic safety due to a pothole. The pothole was the least of the problems. A core sample program was started first and did not find any problems. The client heard about our void imaging services and requested a 2nd look.



Existing Pothole

Metal access
cover

Multiple core locations

Pavement Evaluation

As evident in the image, the core sample program missed the large voids entirely.

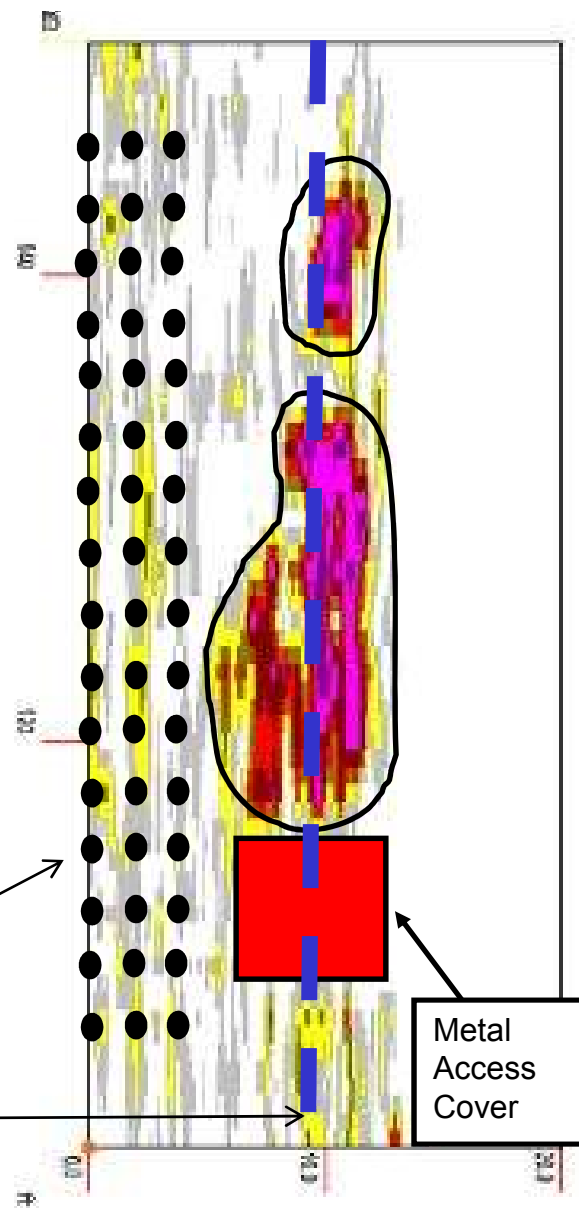
Voids Found

5' x 2' x 2' deep

18' x 7' x 2' deep

Multiple core locations

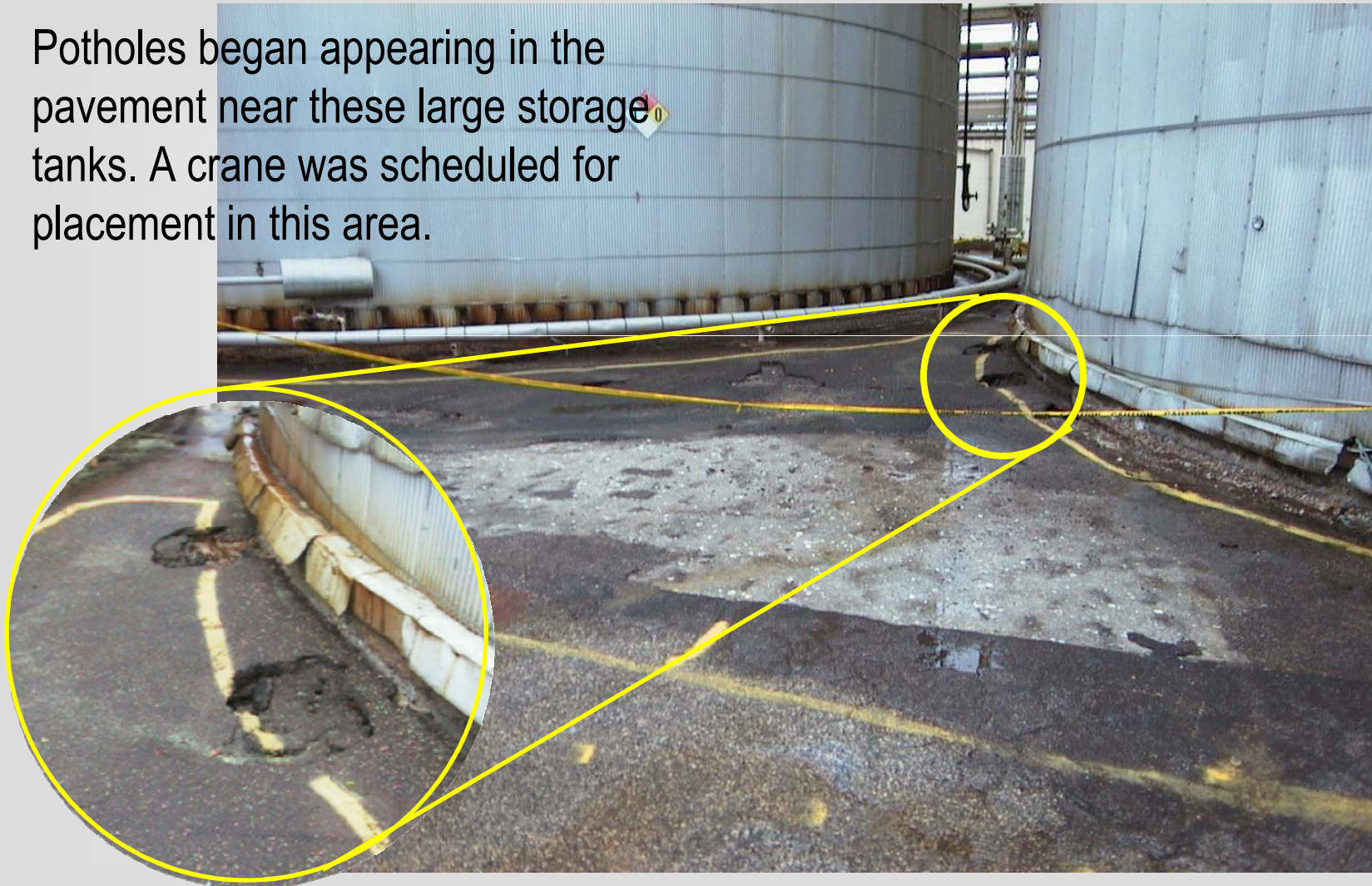
Underground Pipe



Settlement of pavement around storage
tanks within an industrial facility

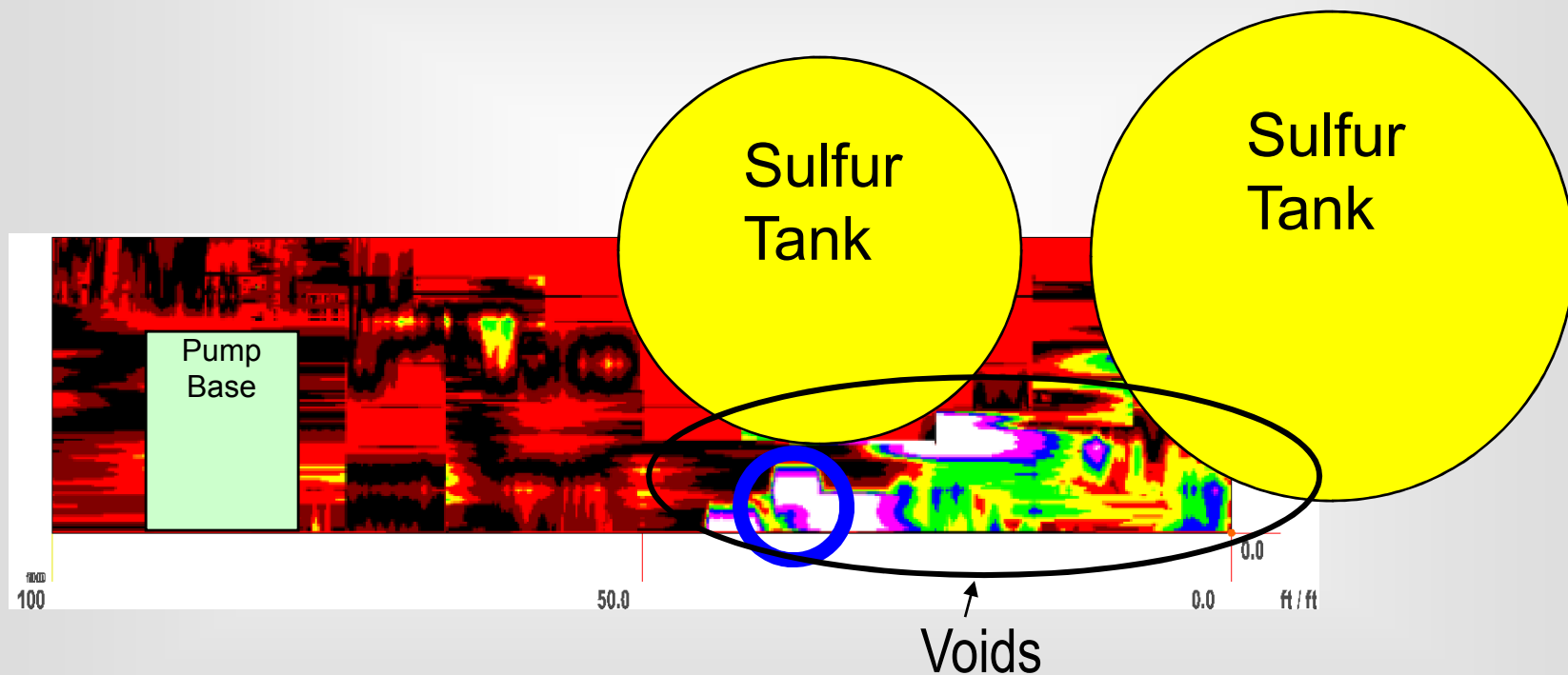
Pavement Evaluation

Potholes began appearing in the pavement near these large storage tanks. A crane was scheduled for placement in this area.



Pavement Evaluation

The outline below shows the intermittent void area detected beneath the pavement. Erosion of soil from a nearby leaking acid cooling tower was the cause.



Pavement Evaluation

Leaking Cooling Unit eroded the soil underneath the pavement and deteriorated the concrete as well.



Consequences of unknown voids / sinkholes



- Safety
- Environmental
- Structures

Consequences of unknown voids / sinkholes



This truck is sitting above another sinkhole

6" Clay Water Pipe

2" Gas Pipe

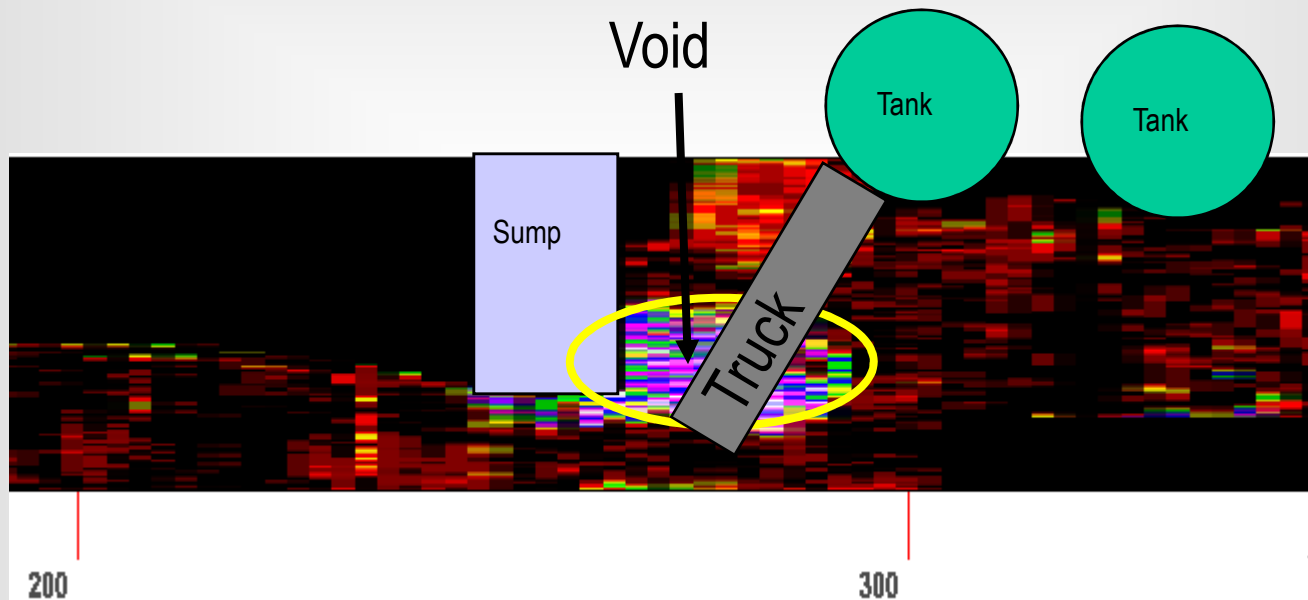
Consequences of unknown voids / sinkholes



6" Clay Pipe

Consequences of unknown voids / sinkholes

The truck that was shown two slides before is outlined below. Another large void was detected where the truck was parked.



Wharf & bulkhead surveys

Wharf Surveys / bulkhead walls

This wharf had some visible depressions present and one pothole. The owner had leased the spaced for 3 new cement silos. Concern about the heavy loads prompted a void survey.

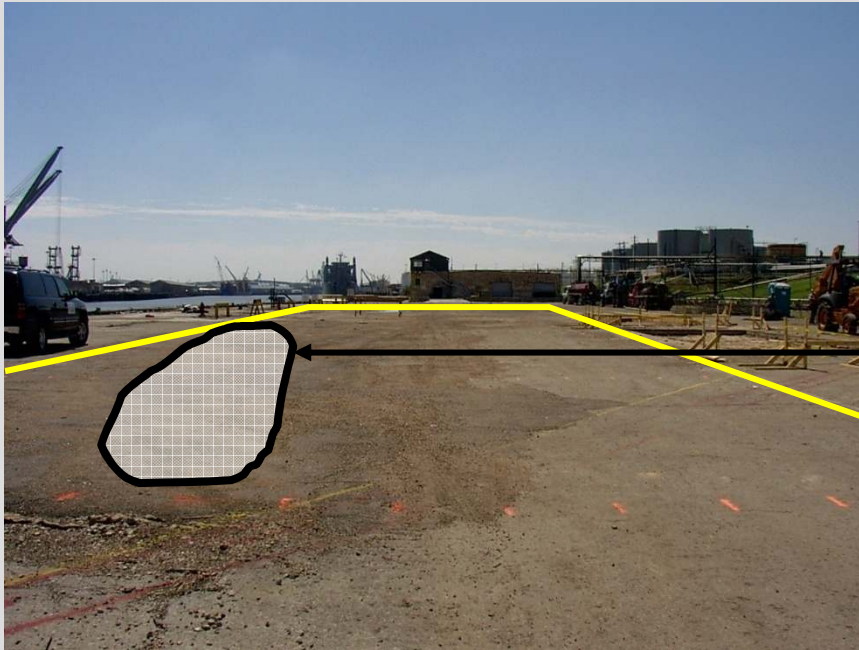


Wharf Surveys / bulkhead walls

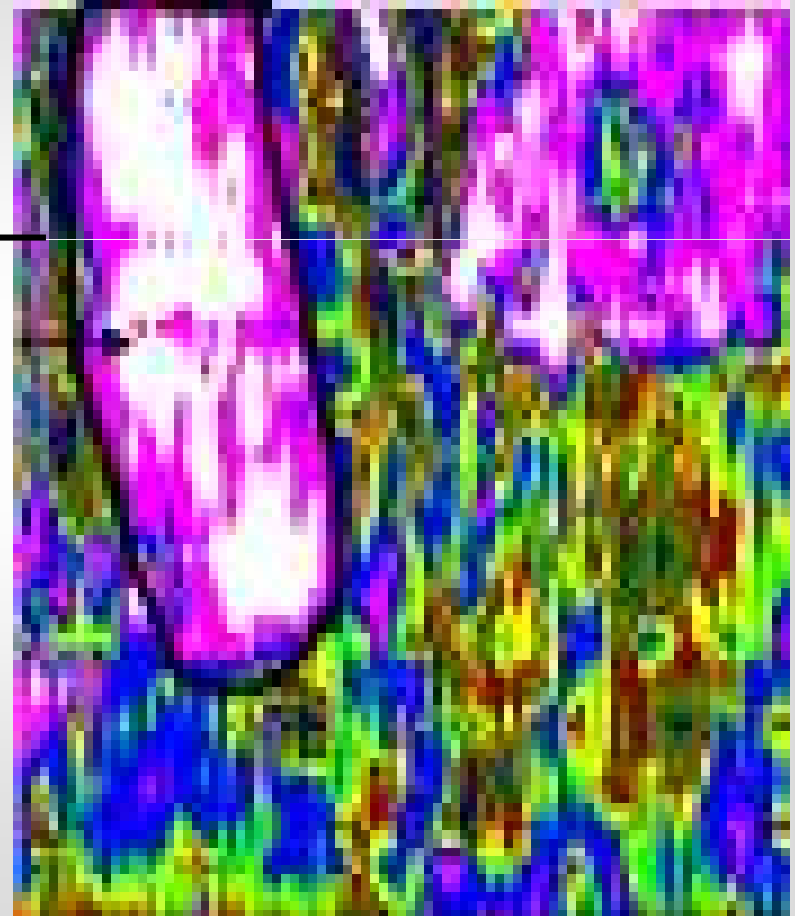
Pot holes tell you that a larger problem may exist below ground.
Note the heavy truck traffic in the area.



Wharf Surveys / bulkhead walls

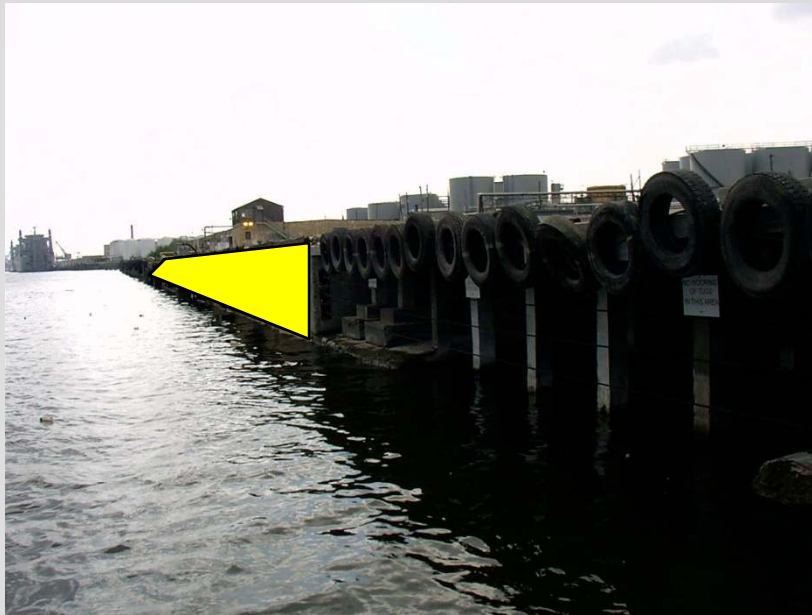


Void



There was a void over 100ft x 25 ft in area. Only the pot hole indicated there was a problem. 6 months after this survey, a crane fell through the pavement. The owner had not repaired the void.

Wharf Surveys / bulkhead walls



This concrete bulkhead was examined for voids – work was performed from a boat. The area in yellow to the left was examined and the data image below shows the void in an elevation view.



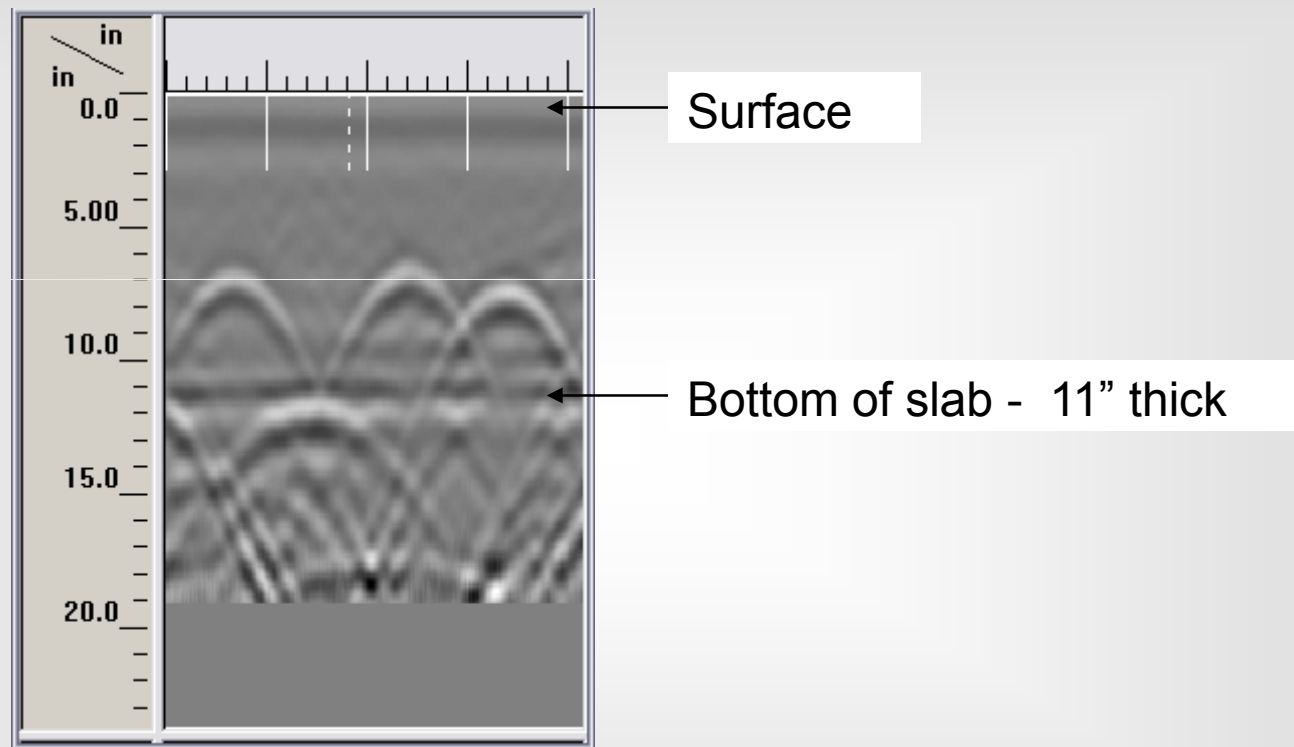
Concrete Bulkhead Wall

- **GPR**

- **Impact-Echo**

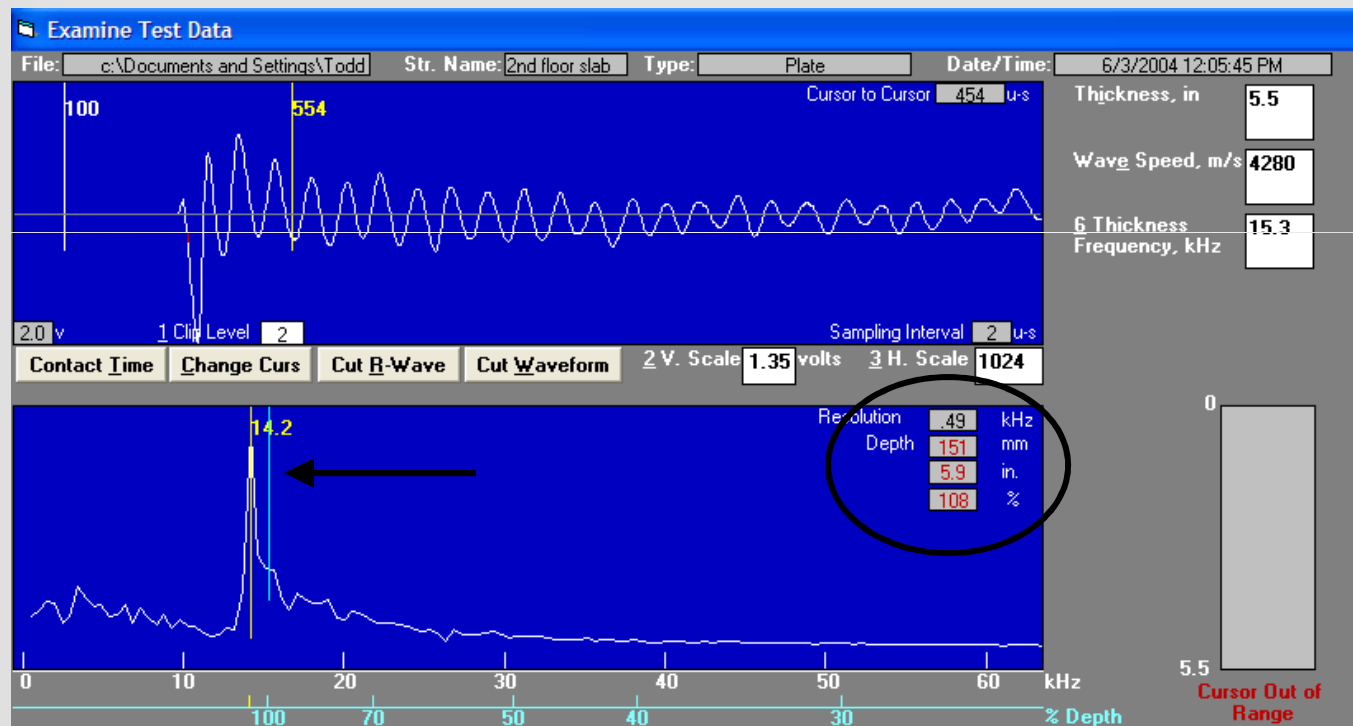
 - **ASTM Standard C 1383-98a**

Concrete Thickness



Elevation View

Concrete Thickness



Thickness frequency analysis > 14.2 kHz > 5.9" thick

Locating poor consolidation/honeycombs

■ Impact-Echo

–ASTM Standard C 1383-98a

Locating poor consolidation/honeycombs

When the forms were removed from this concrete wall, it was apparent that there were quality problems with the concrete mix.

Honeycombs/voids were seen visually. An examination was requested to see if the entire wall was affected. In the end the wall was repaired by injection with epoxy.



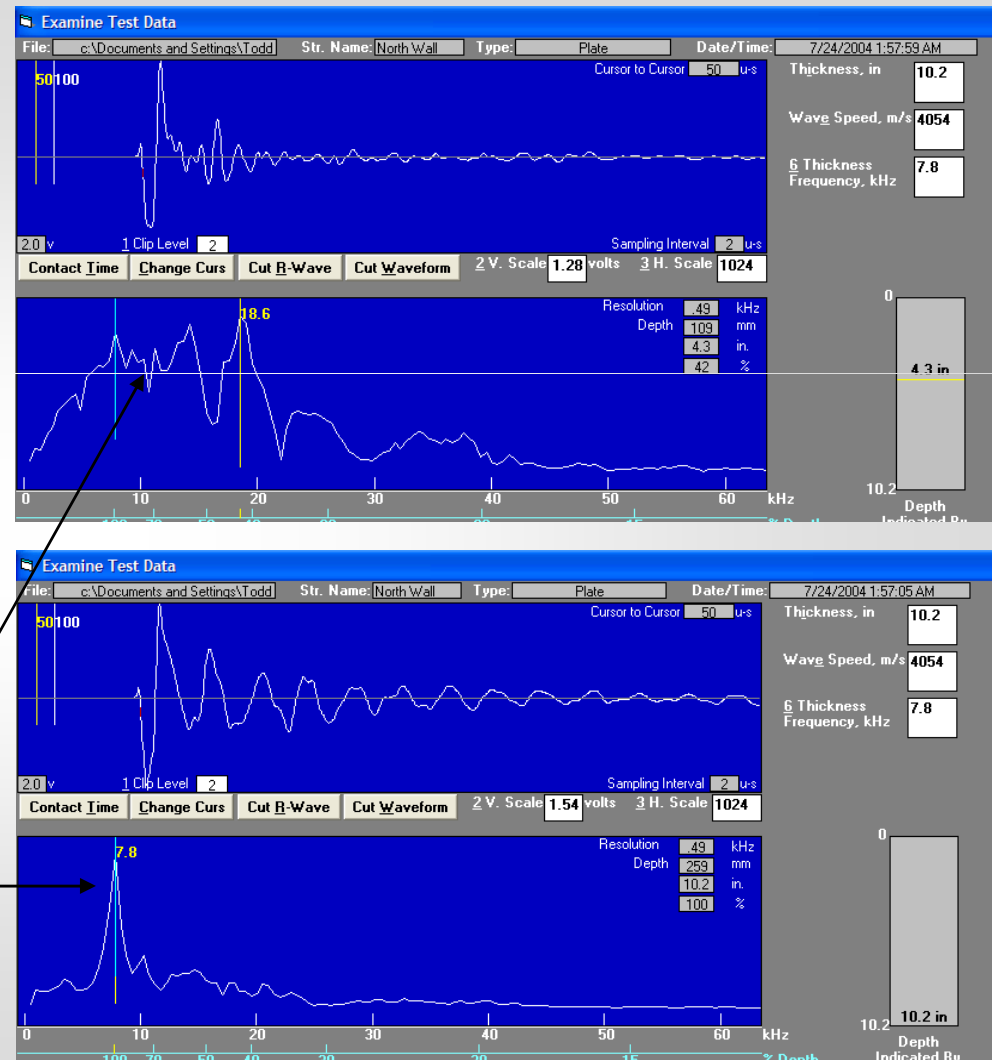
Locating poor consolidation/honeycombs

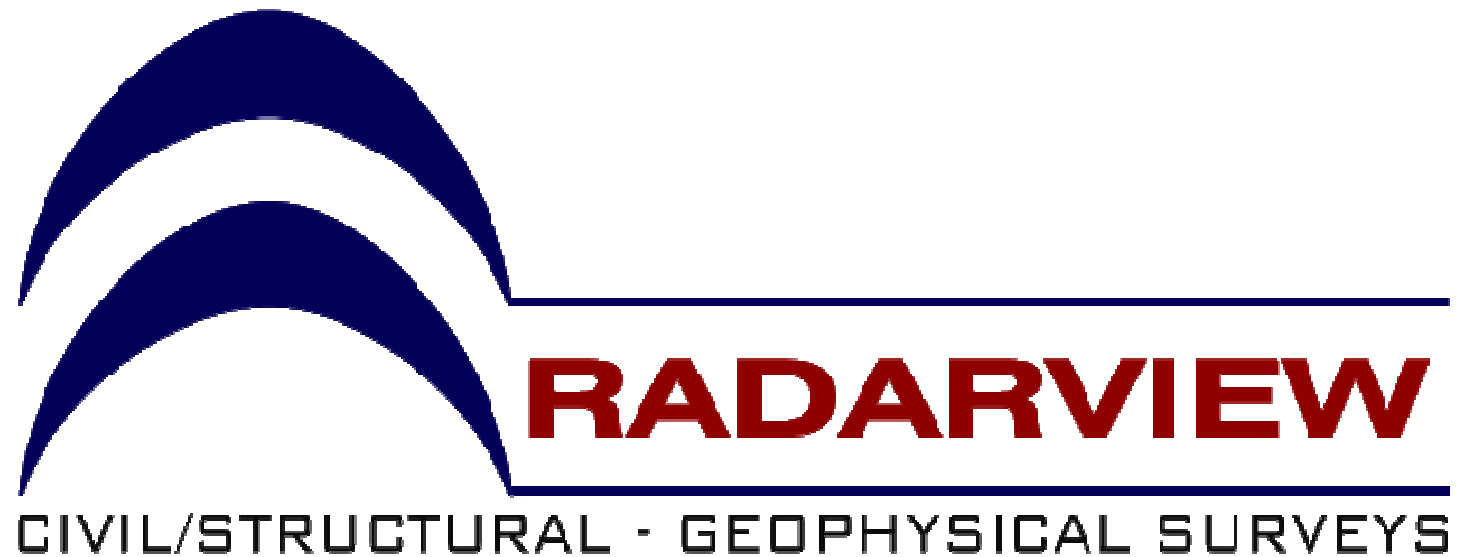
Examples of data from the examination.



Poor consolidation

Well consolidated
concrete





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